Description

Improved Downhole Tool Liner

FEDERAL RESEARCH STATEMENT

[0001] This invention was made with government support under Contract No. DE-FC26-97FT343656 awarded by the U.S. Department of Energy. The government has certain rights in the invention.

BACKGROUND OF INVENTION

[0002] 1. Field of the Invention.

[0003] This invention relates to oil and gas drilling, and more particularly to apparatus and methods for reliably transmitting information along downhole drilling strings.

[0004] 2. Background of the Invention.

[0005] In the downhole drilling industry, MWD and LWD tools are used to take measurements and gather information with respect to downhole geological formations, status of downhole tools, conditions located downhole, and the like. Such data is useful to drill operators, geologists, en-

gineers, and other personnel located at the surface. This data may be used to adjust drilling parameters, such as drilling direction, penetration speed, and the like, to accurately tap into an oil, gas, or other mineral bearing reservoirs. Data may be gathered at various points along the drill string. For example, sensors, tools, and the like may be located at or near the bottom hole assembly and on intermediate tools located at desired points along the drill string.

[0006] Nevertheless, data gathering and analysis represent only certain aspects of the overall process. Once gathered, apparatus and methods are needed to rapidly and reliably transmit the data to the earth"s surface. Traditionally, technologies such as mud pulse telemetry have been used to transmit data to the surface. However, most traditional methods are limited to very slow data rates and are inadequate for transmitting large quantities of data at high speeds.

[0007] In order to overcome these limitations, various efforts have been made to transmit data along electrical or other types of cable integrated directly into drill string components, such as sections of drill pipe. In such systems, electrical contacts or other transmission elements are

used to transmit data across tool joints or connection points in the drill string. Nevertheless, many of these efforts have been largely abandoned or frustrated due to unreliability and complexity.

[0008] For example, one challenge is effectively integrating a transmission line into a downhole tool, such as a section of drill pipe. Due to the inherent nature of drilling, most downhole tools have a similar cylindrical shape defining a central bore. The wall thickness surrounding the central bore is typically designed in accordance with weight, strength, and other constraints imposed by the downhole environment. In some cases, milling or forming a channel in the wall of the downhole tool to accommodate the transmission line may excessively weaken the wall. Thus, in certain embodiments, the only practical route for the transmission line is through the central bore of a downhole tool.

[0009] Nevertheless, routing the transmission line through the central bore may expose the transmission line to drilling fluids, cements, wireline tools, or other substances or objects passing through the central bore. This can damage the transmission line or cause the transmission line to interfere with objects or substances passing through the

central bore. Moreover, in directional drilling applications, downhole tools may bend slightly as a drill string deviates from a straight path. This may cause the transmission line to deviate away from the inside surface of the central bore, thereby worsening the obstruction within the central bore.

[0010] Thus, what are needed are apparatus and methods to protect a transmission line, routed through the central bore of a downhole tool, from drilling fluids, cement, wireline tools, or other components traveling through the central bore.

[0011] What are further needed are apparatus and methods to maintain a transmission line against the inside surface of the central bore even when the downhole tool bends or deviates from a linear path.

[0012] What are further needed are apparatus and methods for lining the inside surface of the central bore to isolate a transmission line from objects or substances traveling through the central bore.

SUMMARY OF INVENTION

[0013] In view of the foregoing, it is a primary object of the present invention to provide apparatus and methods for protecting a transmission line, routed through the central

bore of a downhole tool, from drilling fluids, cement, wireline tools, or other components traveling through the central bore. If is a further object to maintain a transmission line against the inside surface of the central bore even when the downhole tool bends or deviates from a straight path. It is yet a further object to provide apparatus and methods for lining the inside surface of the central bore to isolate a transmission line from objects or substances traveling through the central bore.

[0014] Consistent with the foregoing objects, and in accordance with the invention as embodied and broadly described herein, a liner insertable into the central bore of a downhole tool, wherein the central bore has a standard diameter along a central portion of the tool, and a narrower diameter near the ends of the downhole tool, is disclosed in one embodiment of the invention as including a resilient material rolled into a substantially cylindrical shape. The outside diameter of the resilient material is variable to allow the resilient material to move through the narrower diameter of the central bore. Once past the narrower diameter of the central bore, the outside diameter of the resilient material self-expands within the standard diameter of the downhole tool.

[0015] In selected embodiments, the outside diameter of the resilient material expands to contact the inside surface of the central bore. In other embodiments, a transmission line is routed between the central bore and the outside diameter of the resilient material. The resilient material may keep the transmission line in contact with the inside surface of the central bore. The resilient material may also be effective to protect the transmission line from materials traveling through the central bore.

[0016] In certain embodiments, a channel is formed in the resilient material to accommodate the transmission line. In other embodiments, the resilient material includes two mating surfaces that come together to form the cylindrical shape. Movement between these mating surfaces is effective to cause a change in diameter of the resilient material. In selected embodiments, the mating surfaces are sealed together to prevent substances from leaking into or out of the liner. In certain embodiments, once the resilient material has expanded within the central portion of the downhole tool, the resilient material is maintained in place by shoulders in the central bore.

[0017] In another aspect of the invention, a method for lining the central bore of a downhole tool, wherein the central bore

has a central portion of a standard diameter, and tool ends of a narrower diameter, includes rolling a resilient material into a substantially cylindrical shape. The resilient material is then inserted into the central bore through the one of the tool ends into the central portion of the central bore. Once in place, the diameter of the resilient material self-expands within the central portion of the central bore.

[0018] In selected embodiments, the method includes expanding, by the resilient material, the outside diameter of the resilient material to contact the inside surface of the central bore. In other embodiments, the method includes routing a transmission line between the central bore and the outside diameter of the resilient material. The resilient material may maintain contact between the transmission line and the inside surface of the central bore. The resilient material may also protect the transmission line from materials traveling through the central bore.

[0019] In selected embodiments, the method may include forming a channel in the resilient material to accommodate the transmission line. In other embodiments, the resilient material includes two mating surfaces that mate together to form the cylindrical shape. The diameter of the resilient

material may be varied by moving the mating surfaces with respect to one another. In selected embodiments, the method may further include sealing the mating surfaces to one another to prevent substances from leaking into or out of the liner.

[0020] In another aspect of the invention, a method for lining the central bore of a downhole tool includes providing a resilient liner having a substantially cylindrical shape and an outside diameter sized to fit within the central bore. The method further includes inserting the resilient liner into the central bore and expanding, by the resilient material, the outside diameter of the resilient material within the central bore.

Brief Description of Drawings

[0021] The foregoing and other features of the present invention will become more fully apparent from the following description, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only typical embodiments in accordance with the invention and are, therefore, not to be considered limiting of its scope, the invention will be described with additional specificity and detail through use of the accompanying drawings.

[0022] Figure 1 is a cross-sectional view illustrating one embodi-

ment of a drill rig in accordance with the invention.

[0023] Figure 2 is a cross-sectional view illustrating one embodiment of a transmission line integrated into a downhole tool.

[0024] Figure 3 is a cross-sectional view illustrating one embodiment of a transmission line routed through the central bore of a downhole tool when the downhole tool is curved or bent as is customary in directional drilling applications.

[0025] Figure 4 is a perspective view illustrating one embodiment of a downhole tool liner in accordance with the invention.

[0026] Figure 5 is a perspective view illustrating one embodiment of a downhole tool liner in accordance with the invention as it is initially inserted into the central bore of a downhole tool.

[0027] Figure 6 is a cross-sectional view illustrating one embodiment of a downhole tool liner as it is initially inserted into the central bore of a downhole tool.

[0028] Figure 7 is a cross-sectional view illustrating one embodiment of a downhole tool liner after it expands into the larger diameter of the central bore.

[0029] Figure 8 is a cross-sectional view illustrating one embodiment of a downhole tool liner within the central bore of a downhole tool, wherein the liner is used to isolate a trans-

mission line from objects or substances passing through the central bore.

[0030] Figure 9 is a cross-sectional view illustrating one embodiment of a downhole tool liner inserted into the central bore of a downhole tool, wherein the liner includes a channel to accommodate a transmission line.

DETAILED DESCRIPTION

[0031] It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of embodiments of apparatus and methods of the present invention, as represented in the Figures, is not intended to limit the scope of the invention, as claimed, but is merely representative of various selected embodiments of the invention.

[0032] The illustrated embodiments of the invention will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout. Those of ordinary skill in the art will, of course, appreciate that various modifications to the apparatus and methods described herein may easily be made without departing from the essential characteristics of the invention, as described

in connection with the Figures. Thus, the following description of the Figures is intended only by way of example, and simply illustrates certain selected embodiments consistent with the invention as claimed herein.

[0033] Referring to Figure 1, a cross-sectional view of a drill rig 10 is illustrated drilling a borehole 14 into the earth 16 using downhole tools (collectively indicated by numeral 12) in accordance with the present invention. The collection of downhole tools 12 form at least a portion of a drill string 18. In operation, a drilling fluid is typically supplied under pressure at the drill rig 10 through the drill string 18. The drill string 18 is typically rotated by the drill rig 10 to turn a drill bit 12e which is loaded against the earth 16 to form the borehole 14.

[0034] Pressurized drilling fluid is circulated through the drill bit 12e to provide a flushing action to carry the drilled earth cuttings to the surface. Rotation of the drill bit may alternately be provided by other downhole tools such as drill motors, or drill turbines (not shown) located adjacent to the drill bit 12e. Other downhole tools include drill pipe 12a and downhole instrumentation such as logging while drilling tools 12c, and sensor packages, (not shown). Other useful downhole tools include stabilizers 12d, hole

openers, drill collars, heavyweight drill pipe, sub-assemblies, under-reamers, rotary steerable systems, drilling jars, and drilling shock absorbers, which are all well known in the drilling industry.

[0035] Referring to Figure 2, a downhole tool 12 may include a box end 36 and a pin end 36. A pin end 38 may thread into a box end 36, thereby connecting multiple tools 12 together to form a drill string 18. Due to the inherent nature of drilling, most downhole tools 12 are characterized by a similar cylindrical shape defining a central bore 35. The central bore is used to transport drilling fluids, wire-line tools, cement, and the like down the drill string 18.

[0036] The wall thickness 39 around the central bore 35 is typically designed in accordance with weight, strength, and other constraints, needed to withstand substantial torque placed on the tool 12, pressure within the central bore 35, flex in the tool 12, and the like. Because of immense forces placed on the tool 12, milling or forming a channel in the wall of the downhole tool 12 to accommodate a transmission line 34 may excessively weaken the wall. Thus, in selected embodiments, the only practical route for a transmission line 34 is through the central bore 35 of the downhole tool 12.

[0037] Nevertheless, routing the transmission line 34 through the central bore may expose the transmission line 34 to drilling fluids, cements, wireline tools, or other substances or objects passing through the central bore 35. This can damage the transmission line 34 or cause the transmission line 34 to negatively interfere with objects or substances passing through the central bore 35. Thus, in selected embodiments, a transmission line 34 is preferably maintained as close to the wall 39 of the central bore 39 as possible to minimize interference. In selected embodiments, the transmission line 34 is protected by a conduit 34 or other protective covering 34 to protect it from damage.

[0038] As illustrated, at or near the box end 36 and pin end 38 of the tool 12, the central bore 35 may be narrower and the walls 41 may be thicker. This may increase the strength of the downhole tool 12 at or near the tool joints. In addition, this added thickness 41 may enable channels to be milled or formed in the walls 42, 44, to accommodate a transmission line 34 without overly weakening the downhole tool 12. The channels 42, 44 may exit the downhole tool at or near the ends of the downhole tool 12, where the transmission line 34 may be coupled to transmission

elements (not shown) for communicating across tool joints.

[0039] Referring to Figure 3, In an effort to tap into gas, oil, or other mineral deposits, a drill string 18 may be guided or deviate from a linear path. Thus, in selected directional drilling applications, tools 12 may bend to veer off in a desired direction at an angle 32. Since a drill string 18 may consist of many hundreds of sections of drill pipe 12 and other downhole tools 12, the cumulative bend or curve in each tool 12 may enable a drill string 18 to drill horizontally in some cases.

[0040] As was previously mentioned, in order to transmit data up and down the drill string 18, a transmission line 34 may be integrated into a downhole tool 12. If the transmission line 34 is routed through the central bore 35 of the downhole tool 12, the transmission line 34 may separate or detach from the inside surface of the central bore 35 when the downhole tool 12 bends. This may create problems since the transmission line 34 may then obstruct or interfere with fluids, wireline tools, concrete, or other objects or substances traveling through the central bore. In fact, in some cases, when a downhole tool 12, such as a section of drill pipe 12, bends significantly, the transmission

line 34 may actually come into contact with the opposite side 37 of the central bore 35. Thus, apparatus and methods are needed to route a transmission line 34 through the central bore 35 such that the transmission line 34 stays in relatively constant contact with the inside surface of the central bore 35 even when the downhole tool 12 bends.

[0041] Referring to Figure 4, in selected embodiments, a liner 46 may be provided to line the inside surface of the central bore 35. The liner 46 may be used to protect or isolate the transmission line 34 from substances or objects passing through the central bore 35. As illustrated, a liner 46 may be formed from a rolled material and have a substantially cylindrical shape.

[0042] In selected embodiments, the liner 46 may include mating surfaces 50, 52 that contact one another to form the cylinder. The mating surfaces 50, 52 may move with respect to one another to roll the liner 46 more tightly to provide a smaller diameter 54. Thus, the diameter 54 of the liner may be adjusted as needed. This may be helpful to initially insert the liner 46 into the central bore 35 of a downhole tool 12. The liner may be constructed of any suitable resilient material capable of withstanding the

wear of a downhole environment. For example, a liner 46 may be constructed of a material such as metal, plastic, or the like, having sufficient durability and resiliency.

[0043] Referring to Figure 5, a liner 46 like that described in Figure 4 may be inserted into either the box end 36 or pin end 38 of a downhole tool 12. As illustrated, a pin end 38 may include a primary 60 and secondary shoulder 58, and a threaded portion 55, which may contact another downhole tool 12. The primary shoulder 60 may absorb the majority of the stress at the tool joint. Nevertheless the secondary shoulder 58 may also absorb some of the stress at the tool joint. The two shoulders 58, 60 together may create a stronger tool joint than either shoulder by itself.

[0044] As illustrated, a transmission element 56 may be installed into the secondary shoulder 58. The transmission element 56 may be used to transmit a signal across the tool joint by communicating with a corresponding transmission element 56 located on another downhole tool 12 (not shown). The transmission element 56 may transmit energy in several different ways. For example, in selected embodiments, the transmission element 58 may transmit electrical energy by direct electrical contact another trans-

mission element 58.

[0045] In other embodiments, the transmission element 58 may communicate inductively. That is, the transmission element 58 may convert an electrical signal to magnetic energy for transmission across the tool joint. The magnetic energy may then be converted back to an electrical signal by another transmission element 58. To accommodate the transmission element 58, a recess may be formed in the secondary shoulder 58. The transmission line 34 may connect to the transmission element 58 through the channel 44 in the pin end 38.

[0046] As was previously mentioned, the central bore 35 traveling through the pin end 38 may be narrower than the central bore 35 traveling through the central portion of the tool 12. Thus, in order to insert the liner 46 into the downhole tool 12, the diameter 54 of the liner 46 may be reduced. This may be accomplished by rolling the liner 46 into a smaller cylinder. The liner 46 may then be inserted in a direction 62 into the downhole tool 12. In selected embodiments, the liner 46 may be lubricated to facilitate sliding the liner 46 into the tool 12.

[0047] Referring to Figure 6, a cross-sectional view of a liner 46 is illustrated as it is inserted into a downhole tool 12. As

shown, the liner 46 may be inserted with an initial diameter 54 so it can slide through the narrow bore 64 in either the box end 36 or pin end 38. The liner 46 may be cut to a specified length 66 to fit within a central portion 66 of the downhole tool 12.

[0048] Referring to Figure 7, once the liner 46 reaches the central portion 66 of the central bore 35, the diameter 54 of the liner 46 may increase to contact the inside surface of the central bore 35. As was previously described, the liner 46 may self-expand within the central bore 35 due to its resiliency. For example, if the liner 46 is a sheet of a resilient material rolled into a cylindrical shape, the diameter 54 of the liner 46 may automatically expand due to its resiliency.

[0049] Once the diameter 54 of the liner 46 has expanded to contact the inside surface of the central bore 35, the liner 46 may kept in place 12 by shoulders 68a, 68b near the box and pin ends 36, 38. The shoulders 68a, 68b may be present where the central bore 15 narrows near the box end 36 and pin end 38. Likewise, the resiliency of the liner 46 may keep the liner 46 from slipping past the shoulders 68a, 68b. In selected embodiments, the more resilient the material 46, the better the retention between the shoul-

ders 68a, 68b.

[0050] It is important to securely retain the liner 46 between the shoulders 68a, 68b. For example, if the liner 46 slips past the shoulders 68a, 68b, the liner 46 may create an obstruction within the central bore 15. This may cause the drill string to malfunction, possibly causing time-consuming and costly delays. In other embodiments, the liner 46 may be welded or otherwise bonded to the inside of the downhole tool 12 to keep it from moving.

[0051] Referring to Figure 8, a cross-sectional view of the central portion 66 of a downhole tool 12 is illustrated. As shown, the transmission line 34 may be sandwiched between the liner 46 and the surface of the central bore 35. This may protect the transmission line 34 from objects or substances passing through the central bore 35. In selected embodiments, the mating surfaces 50, 52 may be sealed together to prevent fluids or other substances from leaking from the liner 46. In other embodiments, the mating surfaces 50, 52 may be left unsealed.

[0052] Referring to Figure 9, in other embodiments, a channel 70 may be formed in the liner 46 to accommodate the transmission line 34. The channel 70 may maintain the transmission line 34 in place and provide better contact be-

tween the liner 46 and inside surface of the central bore 35.

[0053] The present invention may be embodied in other specific forms without departing from its essence or essential characteristics. The described embodiments are to be considered in all respects only as illustrative, and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes within the meaning and range of equivalency of the claims are to be embraced within their scope.